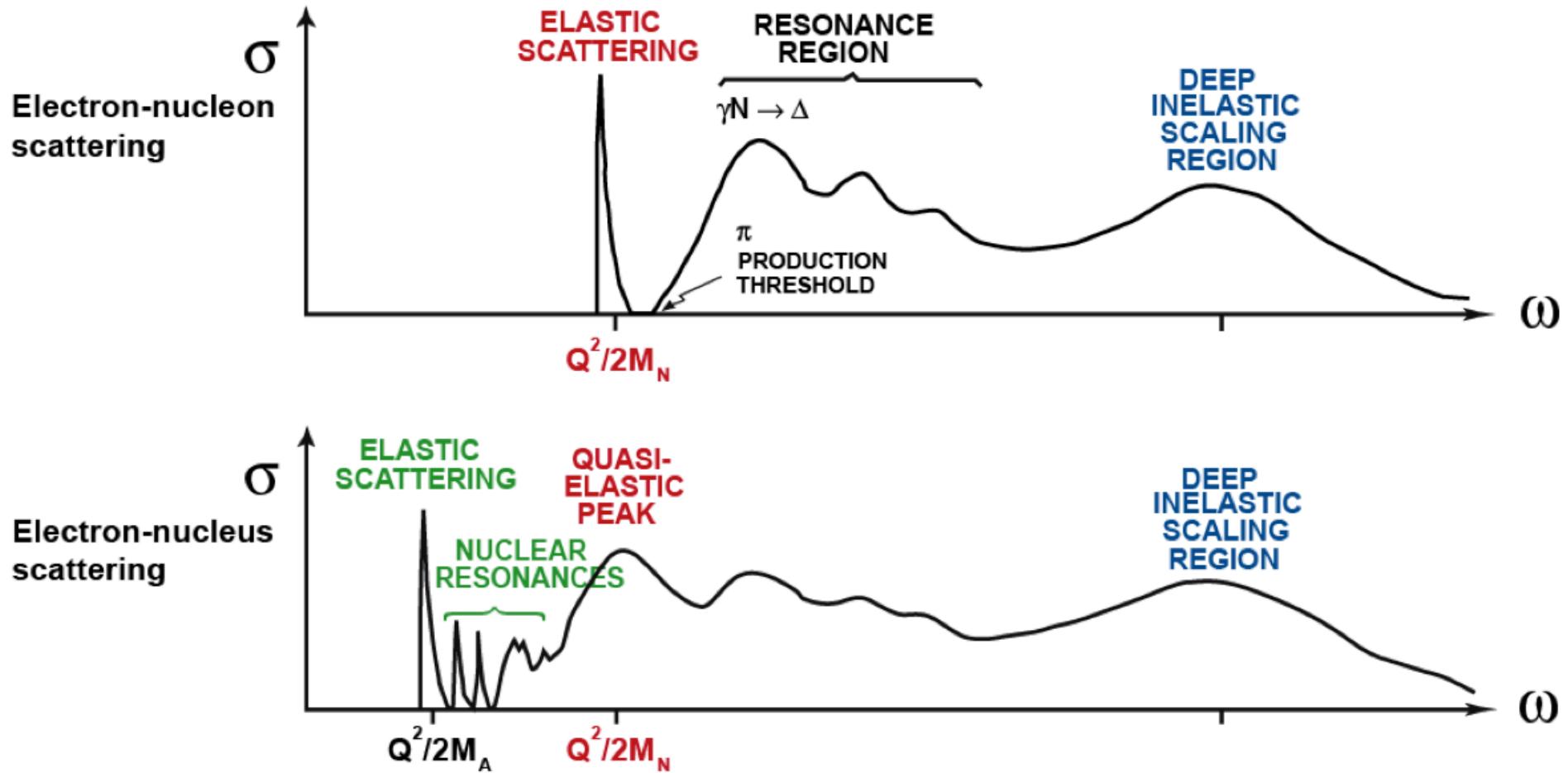
The background of the slide features a dark, abstract composition of several glowing, translucent spheres. These spheres are primarily blue, green, and red, with some containing internal glowing points or patterns. They are set against a backdrop of soft, glowing arcs and circles in shades of purple, blue, and pink, creating a futuristic or scientific atmosphere.

# Effect of Short-Range Interactions on Nuclei

by

Douglas W. Higinbotham

# Electron Scattering from Nucleons in the Nucleus



$$x_B = Q^2/2m\omega$$

$$x_B > 1$$

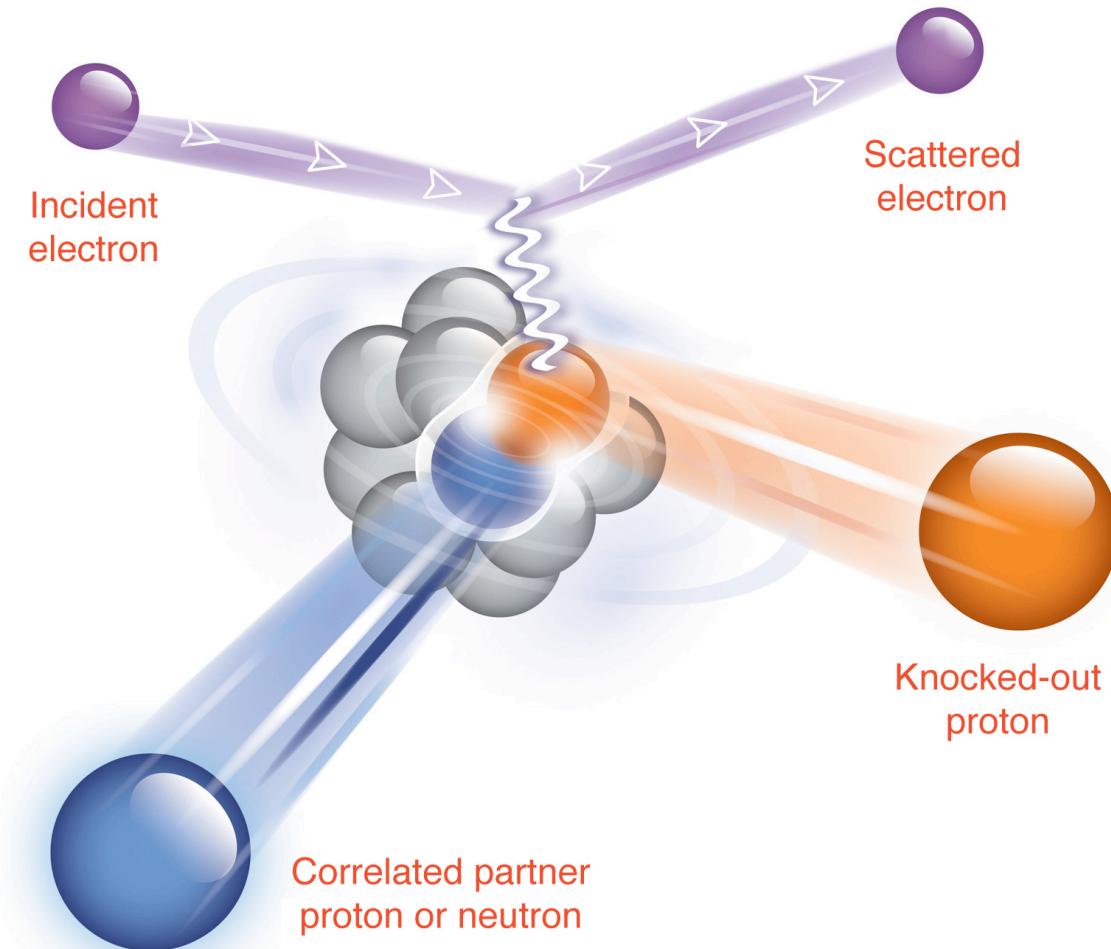
$$x_B = 1$$

$$x_B < 1$$

# Highlights Since 2007 Long Range Plan

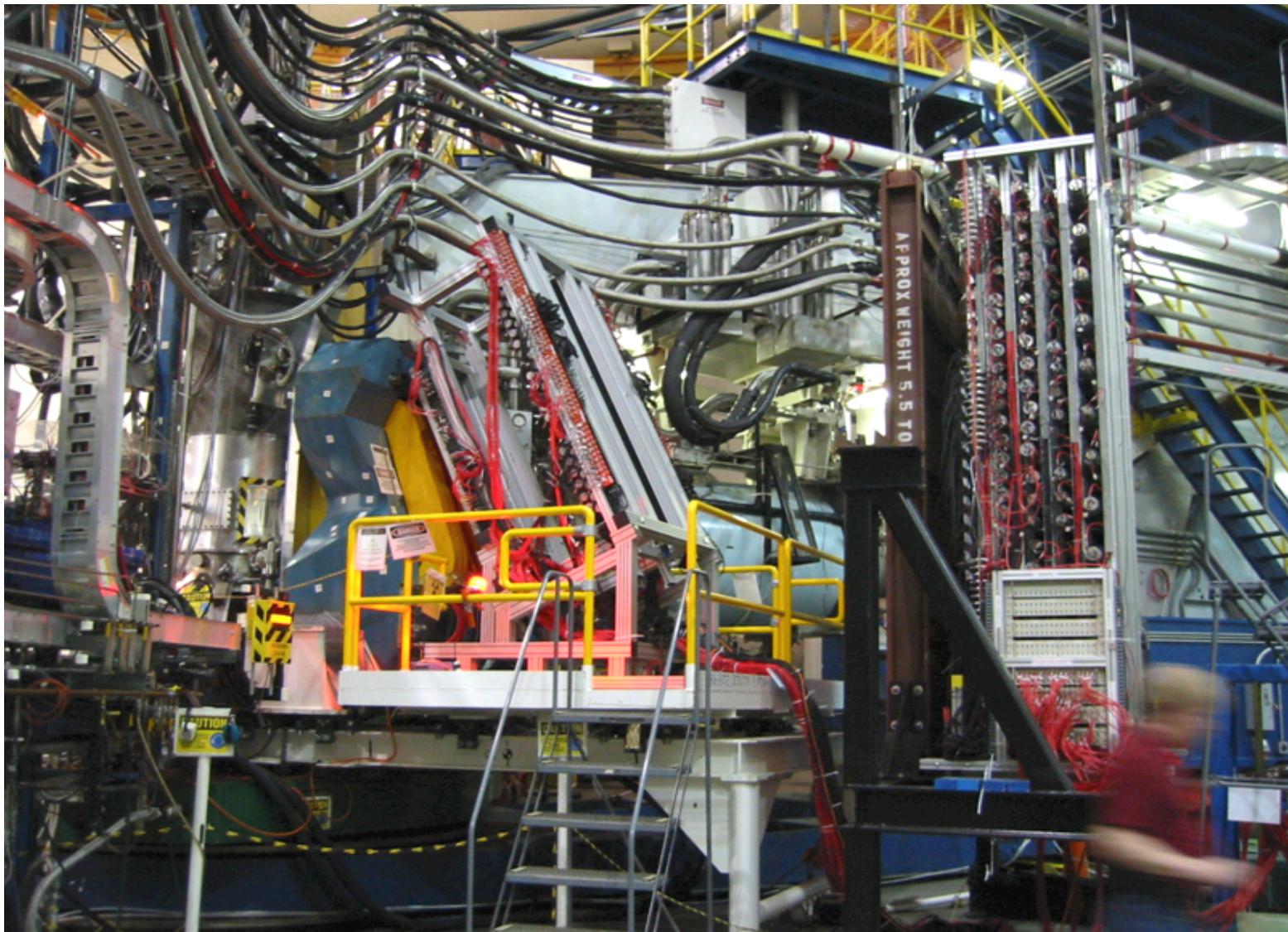
# Coincidence ( $e, e' p N$ ) Measurement

To study nucleon pairs and the fraction that contribute to momentum tail.



$x > 1$ ,  $Q^2 = 1.5 \text{ [GeV/c}^2]$  and missing momentum of 500 MeV/c

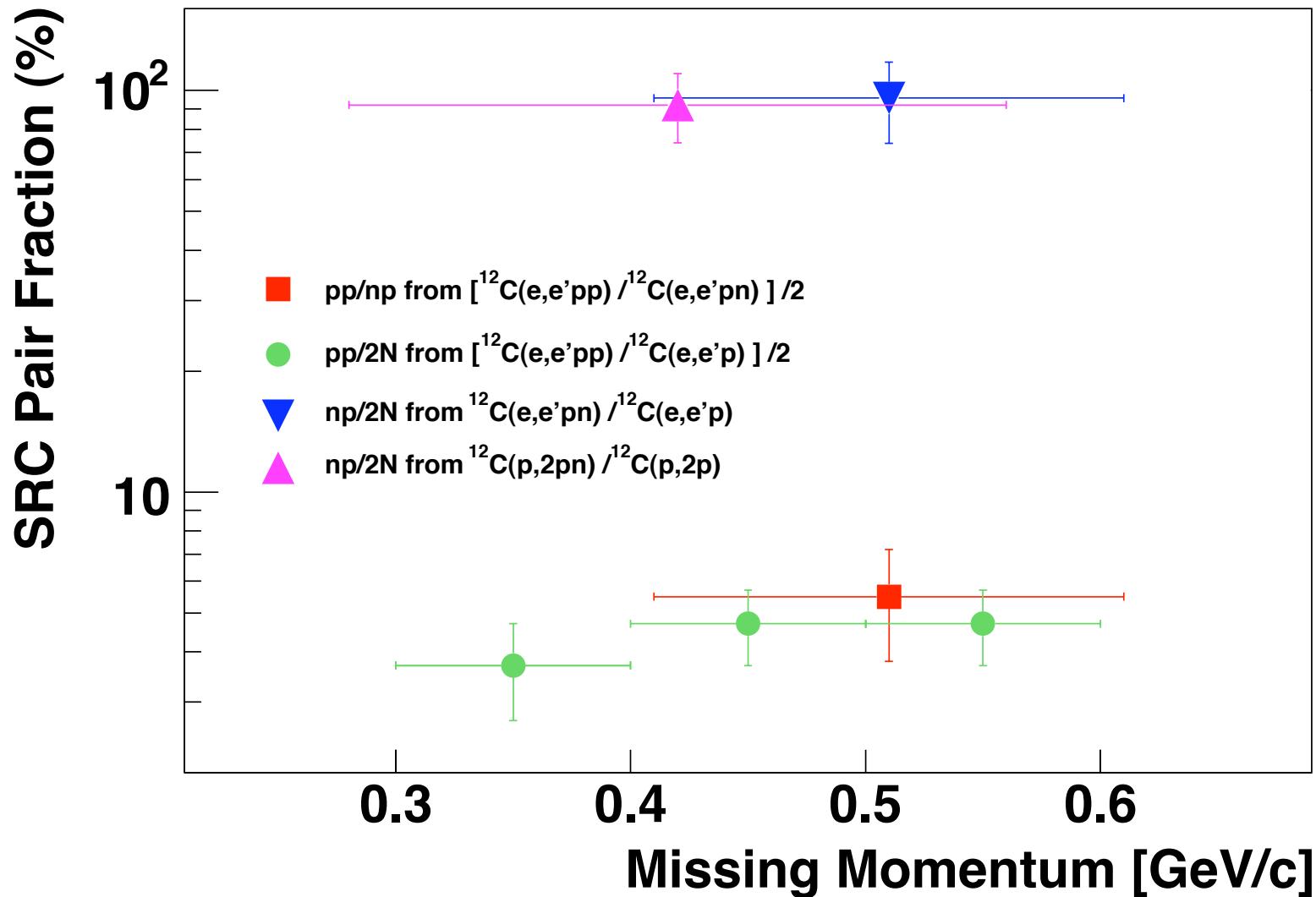
# BigBite and Neutron Detector in Hall A



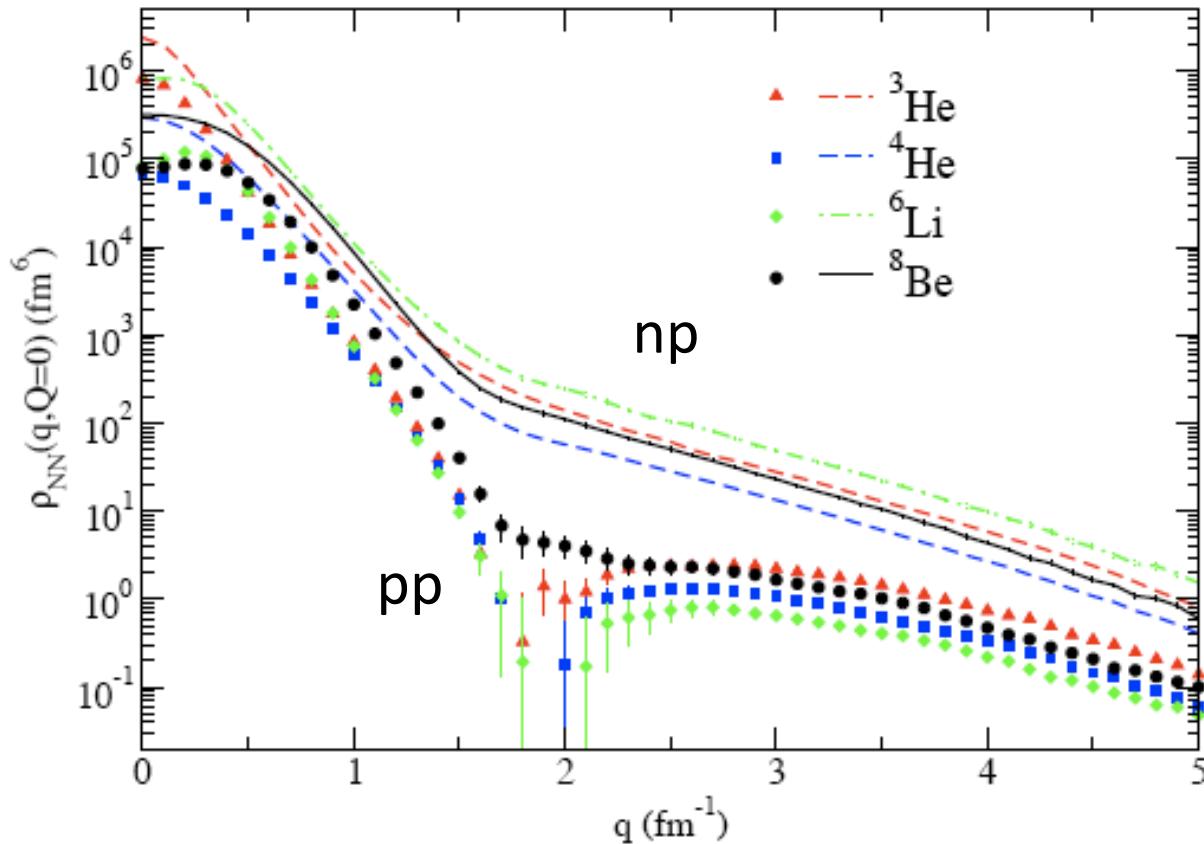
First step along the way to many successful high luminosity, large acceptance measurements.

# High $p_m$ ( $e,e'p$ ) events have recoiling neutrons.

R. Subedi *et al.*, Science **320** (2008) 1476.



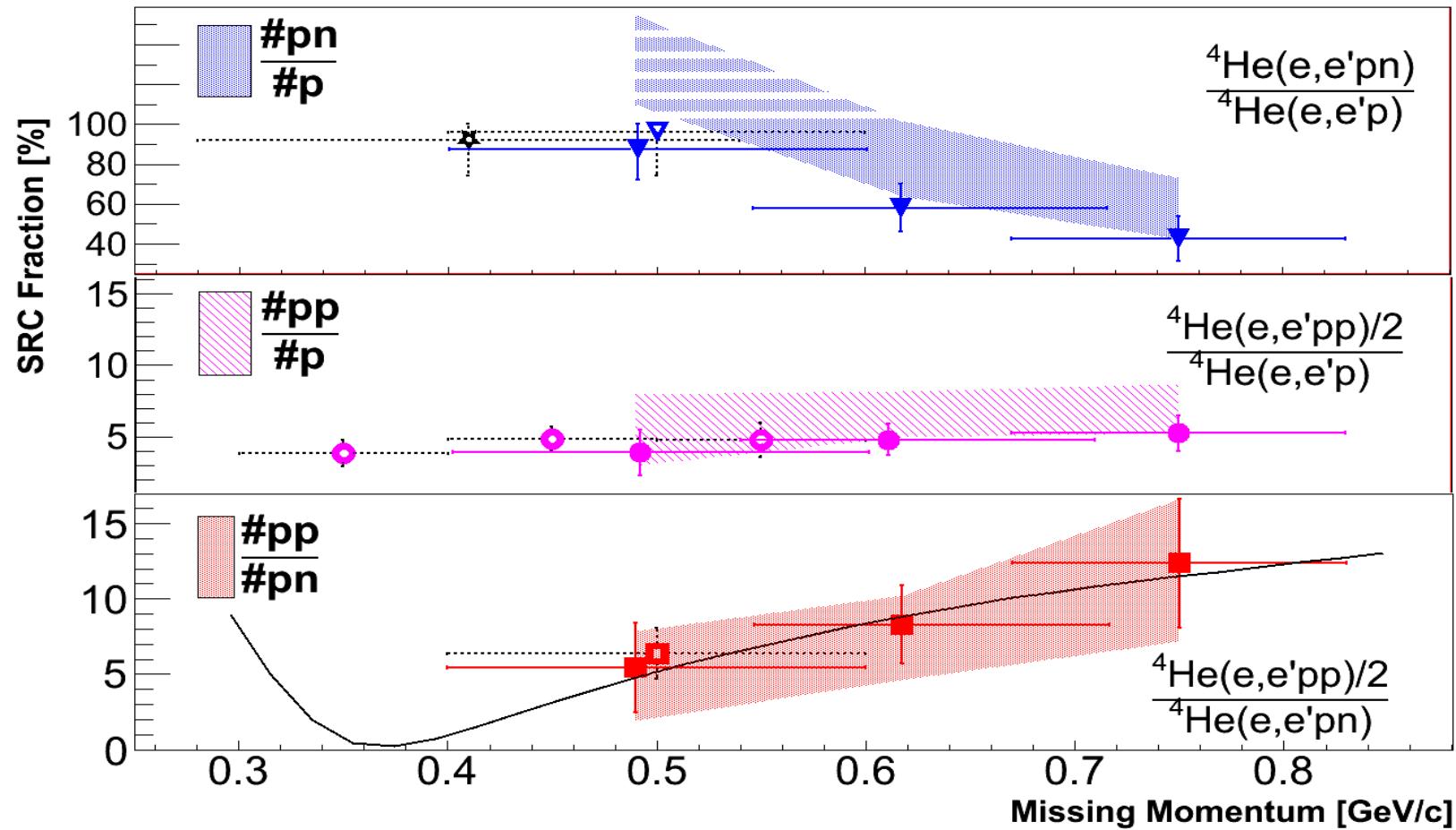
# Importance of Correlations



- R. Schiavilla *et al.*, Phys. Rev. Lett. 98 (2007) 132501.
- M. Sargsian *et al.*, Phys. Rev. C (2005) 044615.
- M. Alvioli *et al.*, Phys. Rev. Lett. 100 (2008) 162503.

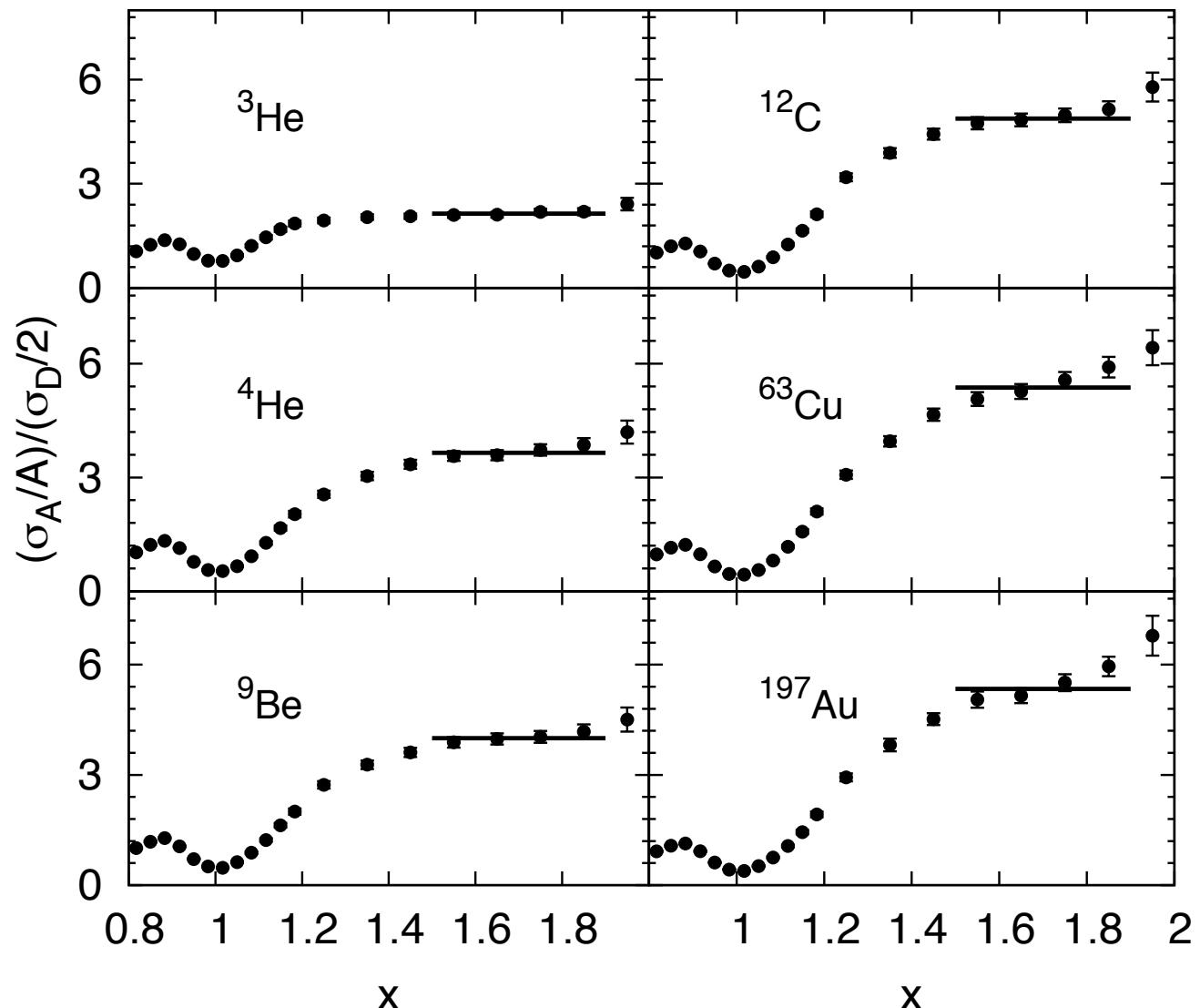
# 2<sup>nd</sup> Generation ${}^4\text{He}(e,e'pn)$ Results

I. Korover *et al.*, Phys. Rev. Lett. **113** (2014) 022501.



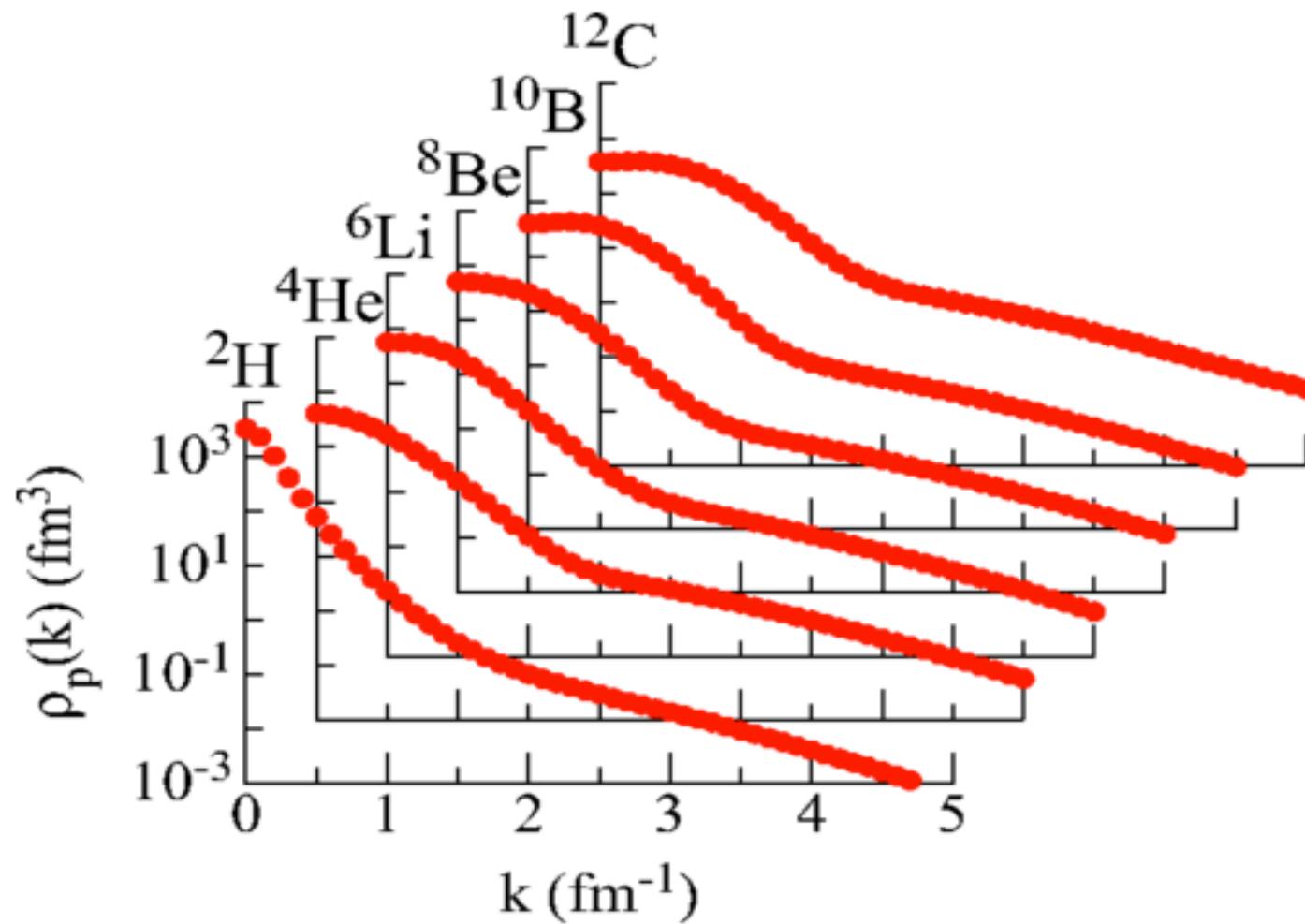
# Precision ( $e, e'$ ) $x > 1$ Cross Section Ratios

N. Fomin *et al.*, Phys. Rev. Lett. **108** (2012) 092502.



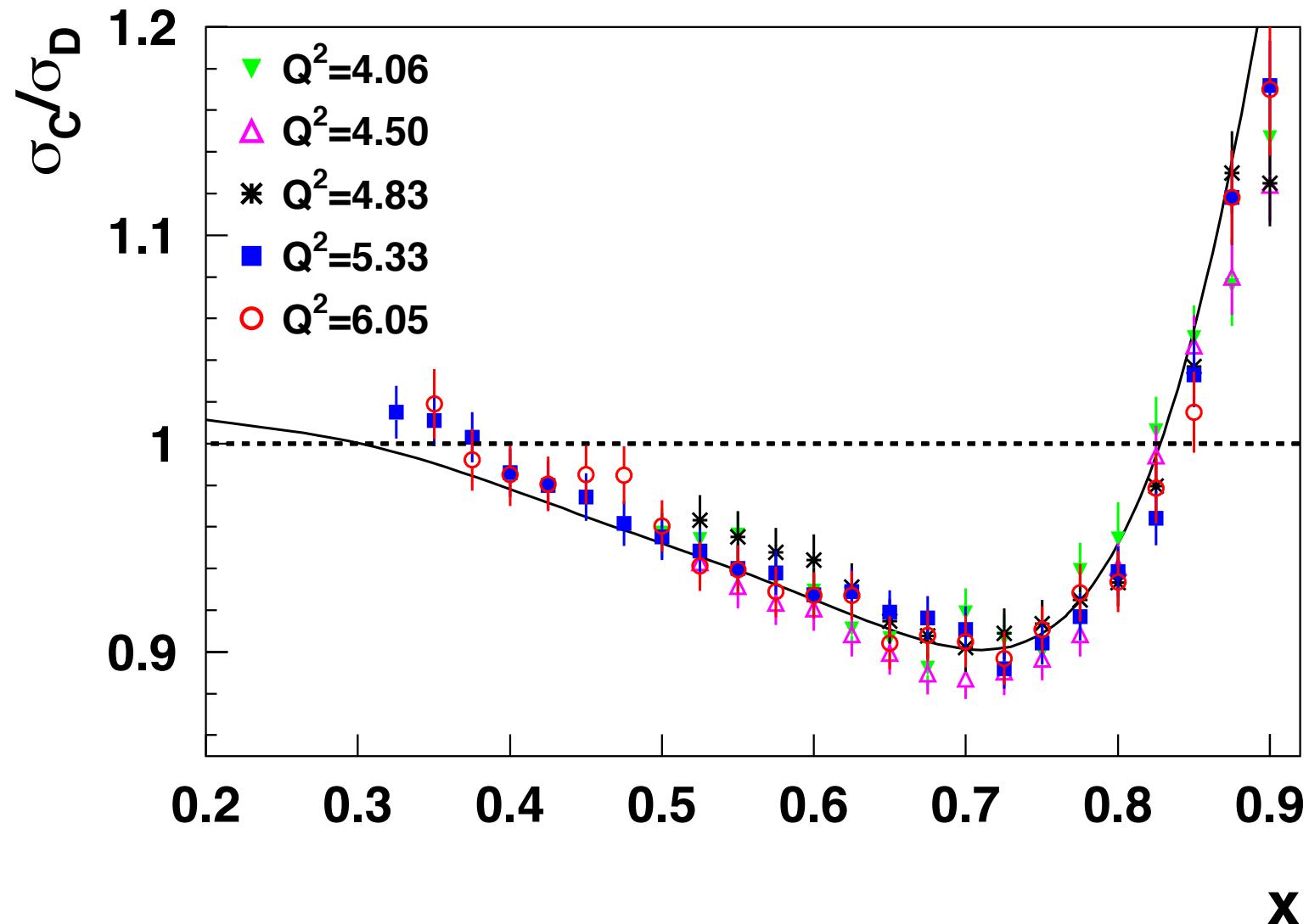
# Modern AV18 and Urbana-X Results

R. Wiringa, R. Schiavilla, S. Pieper, and J. Carlson, Phys. Rev. C89 (2014) 024305.



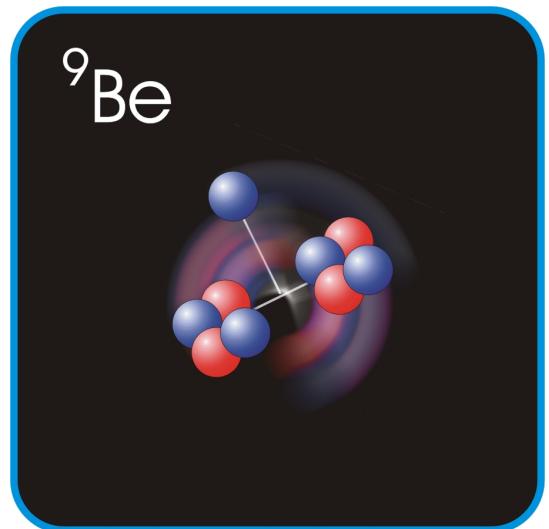
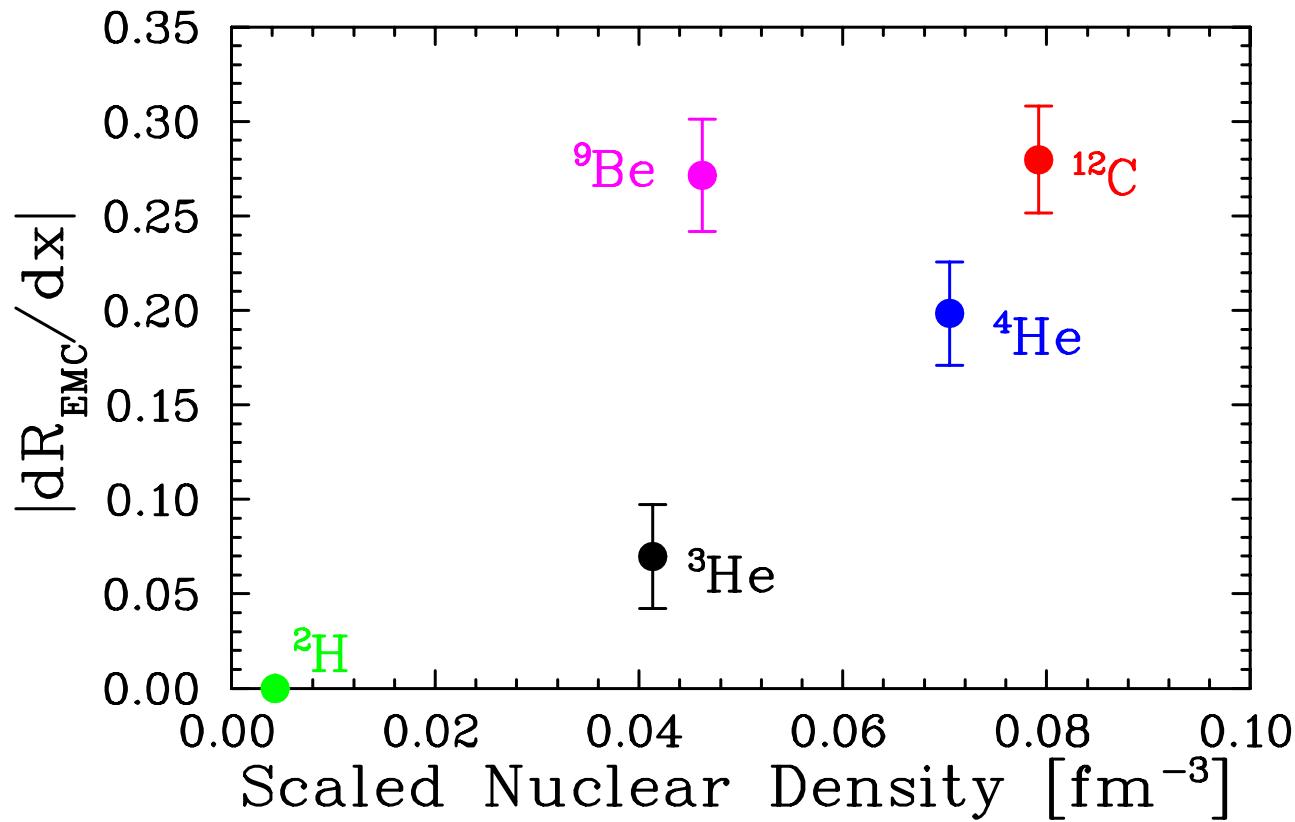
# Jefferson Lab EMC Effect Data

J. Seely *et al.*, Phys. Rev. Lett. **103** (2009) 202301.



# Jefferson Lab EMC Effect Data

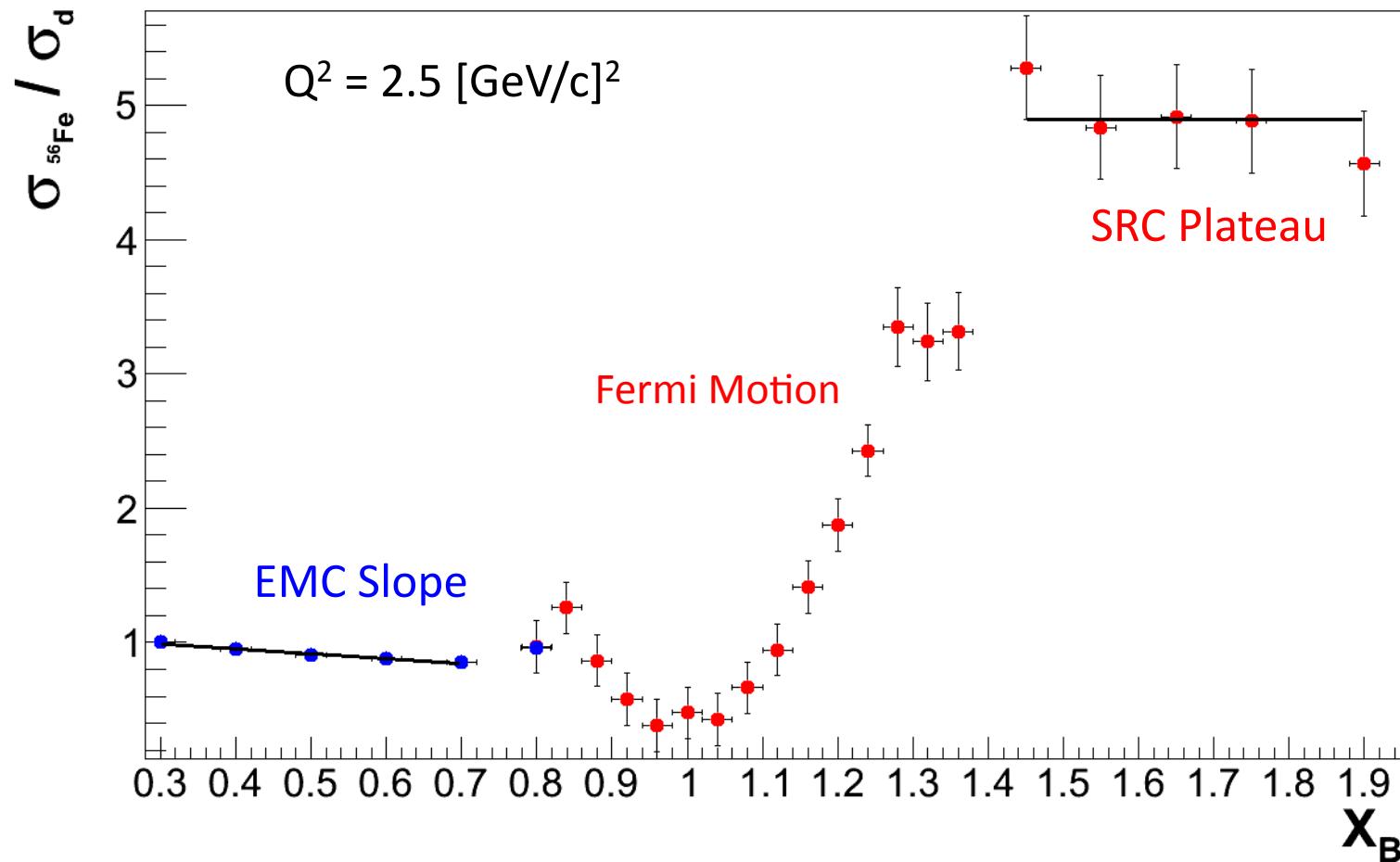
J. Seely *et al.*, Phys, Rev. Lett. **103** (2009) 202301.



- Plot shows slope of ratio  $\sigma_A/\sigma_D$  at EMC region.
- EMC effect correlated with **local density** not average density.

# Holistic View of inclusive EMC & SRC Data

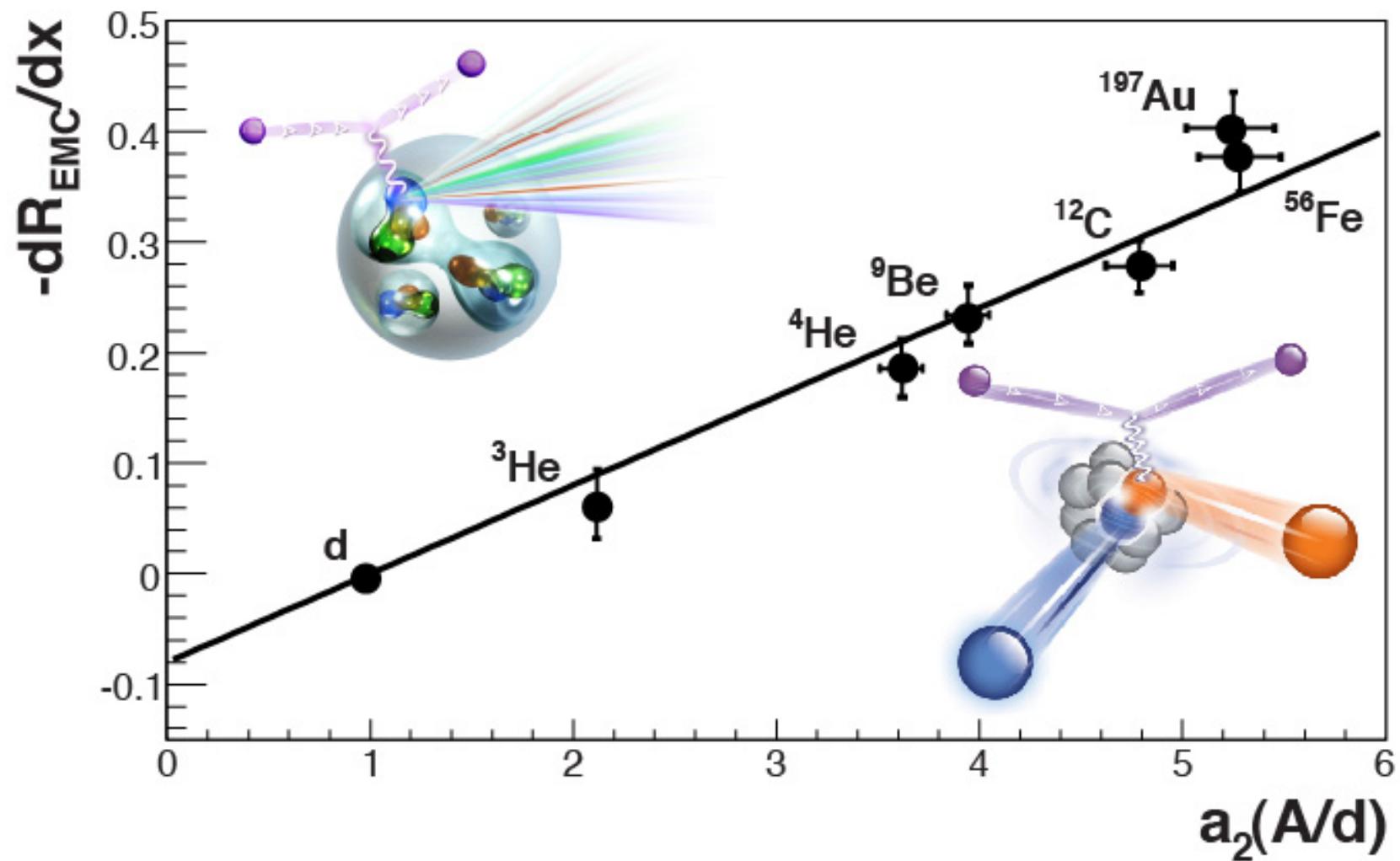
S. Malace, D. Gaskell, D.H., I. Cloet, Int. J. Mod. Phys. E **23** (2014) 1430013



- Scaling plateaus are likely due to proton-nucleon **local density** correlations
- So could the **EMC slopes** ( $x_B < 0.7$ ) and **SRC plateaus** ( $x_B > 1.5$ ) correlated?!

# $x > 1$ Ratios and EMC Slope Correlation

L. Weinstein *et al.*, Phys. Rev. Lett. **106** (2011) 052301.

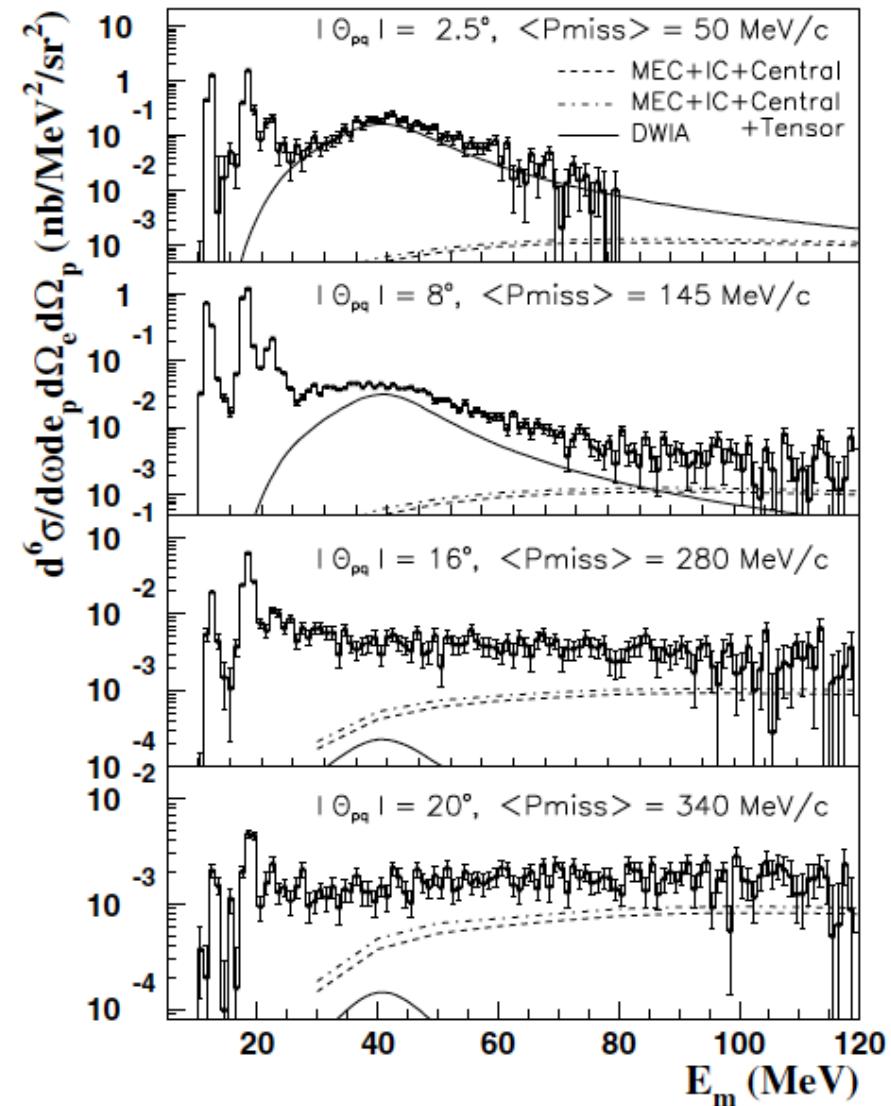
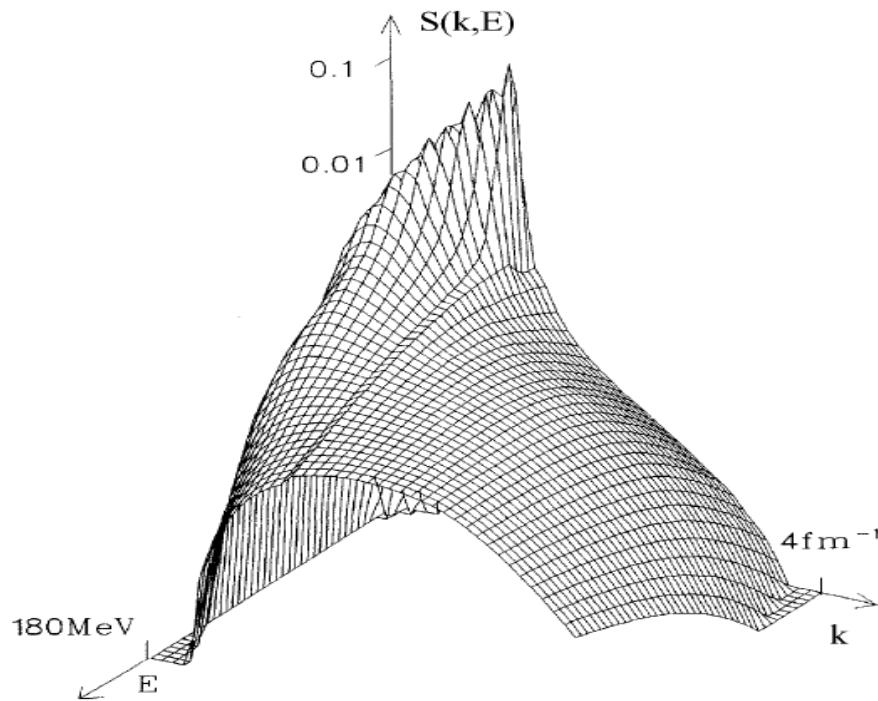


# Future Measurements

# Collaboration with Neutrino Community

E12-14-012: Measurement of the Spectral Function of  $^{40}\text{Ar}$  with the (e,e'p) reaction

- Precision neutrino experiments now require detailed understanding of nuclear structure and reaction mechanisms.
- Nice example of nuclear physics subfields coming together.
- Shown are Jefferson Lab  $^{16}\text{O}(\text{e},\text{e}'\text{p})$  results from N. Liyanage *et al.*, Phys.Rev.Lett. 86 (2001) 5670.



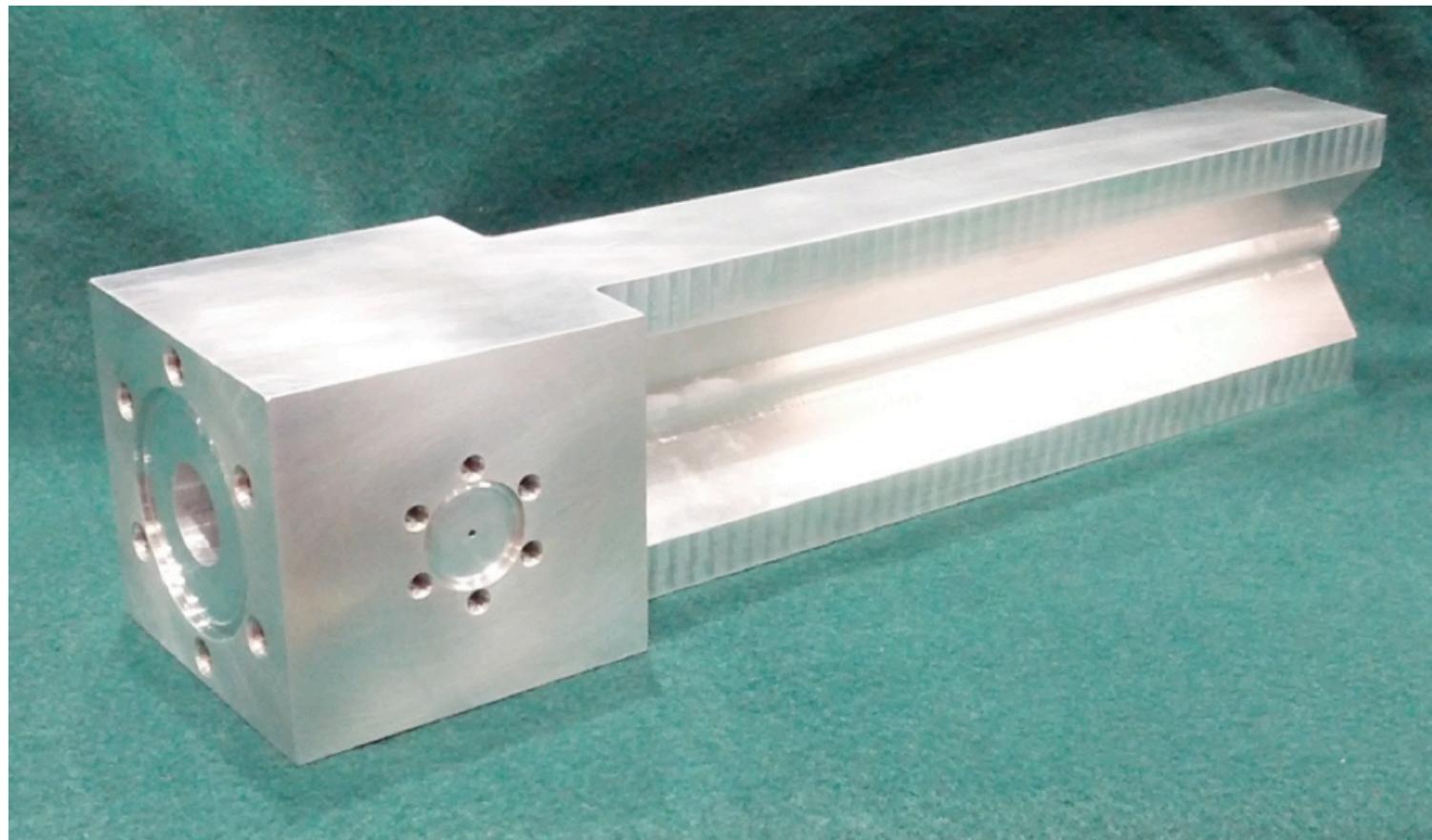
# Triton ( ${}^3\text{He}$ & ${}^3\text{H}$ ) Measurements

E12-10-103: Marathon u/d ratios from  ${}^3\text{He}(e,e')/{}^3\text{H}(e,e')$  DIS measurements

E12-11-112:  $x>1$  measurements of correlations

E12-14-001: elastic scattering measurement to better determine the charge radius

E12-14-012:  $(e,e'p)$  momentum distribution measurements

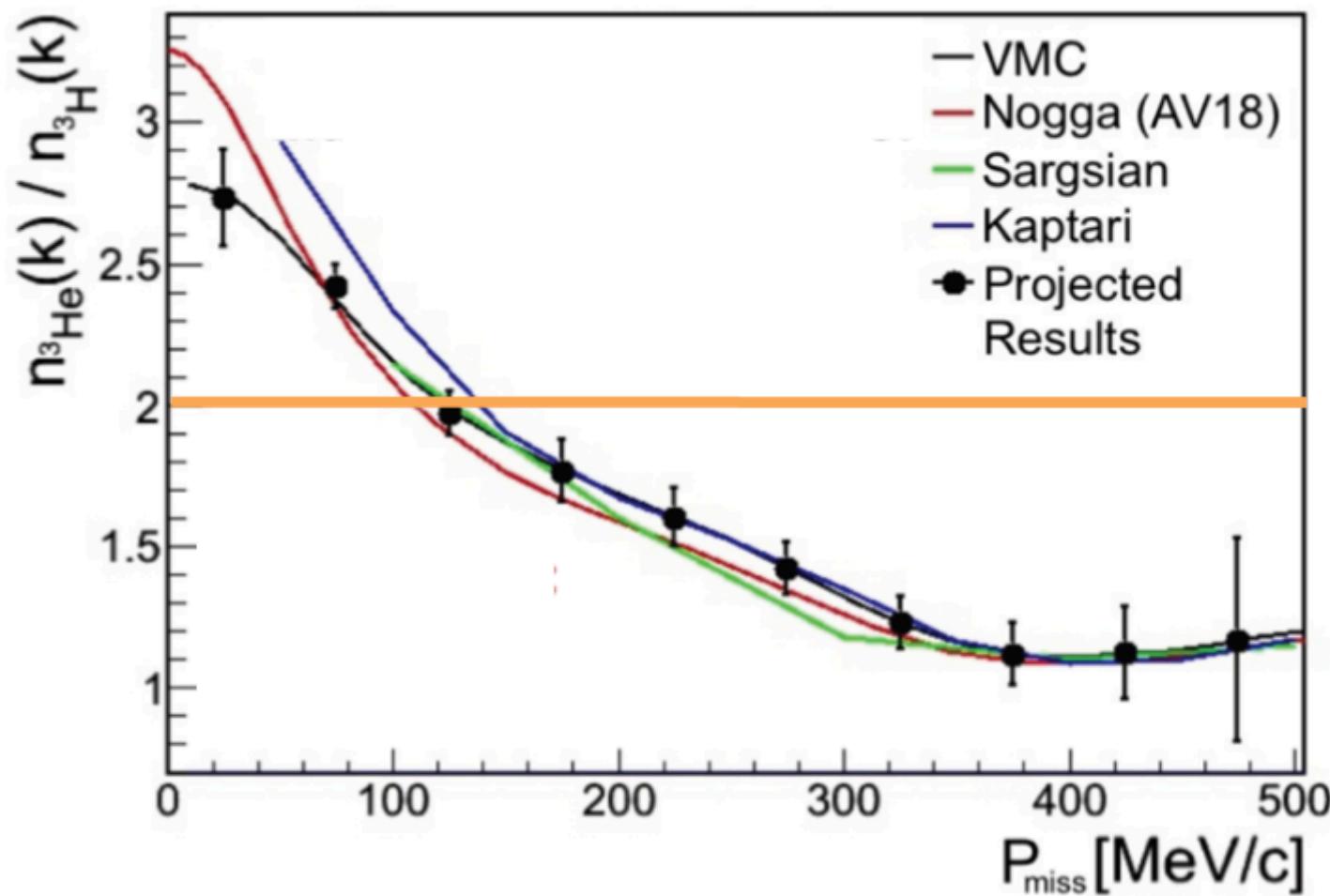


Relatively small amount of tritium ( $\sim 1\text{kC}$ ) in a cell machined from single block of Al.

# $^3\text{He}(\text{e},\text{e}'\text{p})/{}^3\text{H}(\text{e},\text{e}'\text{p})$ Is Two, Isn't It?!

E12-14-011: Proton and Neutron Momentum Distributions in A = 3 Asymmetric Nuclei

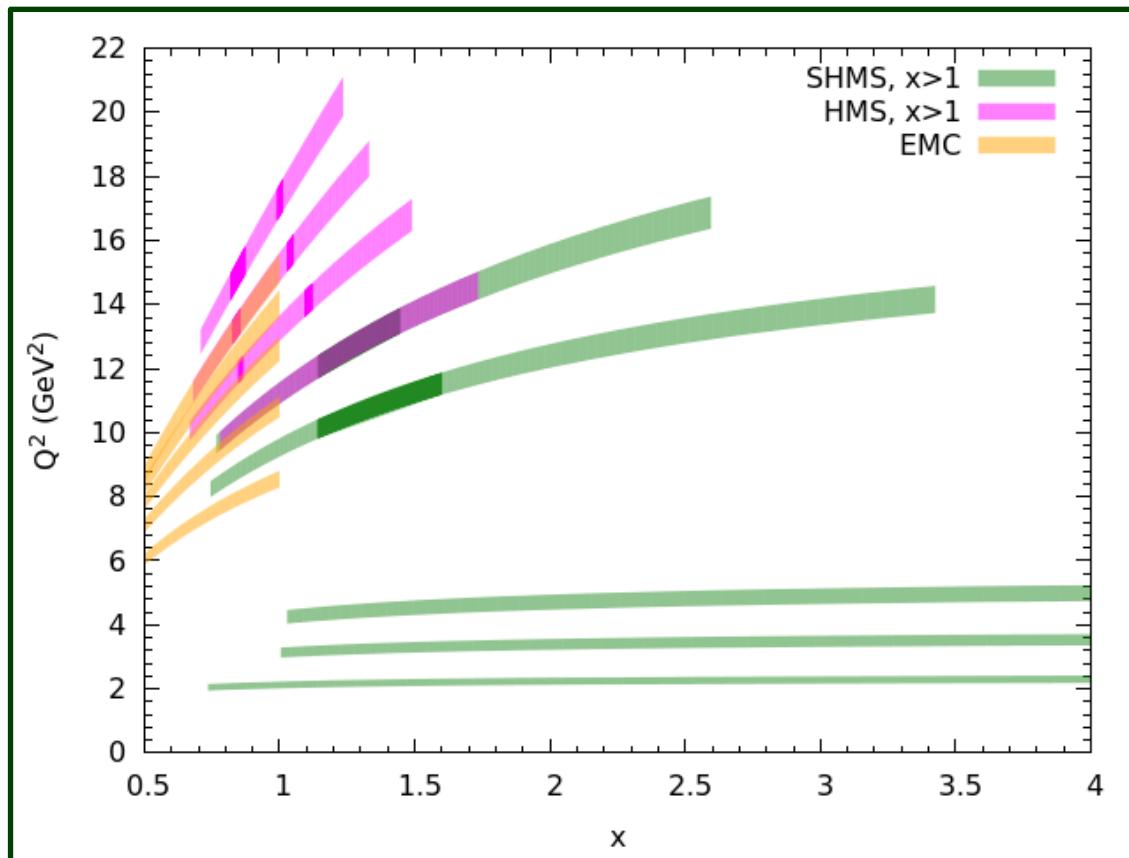
arXiv:1409.1717



# Systematic Study of $x > 1$ Region

E12-06-105: Inclusive Scattering from Nuclei at  $x > 1$  in quasi-elastic & deeply inelastic regimes.

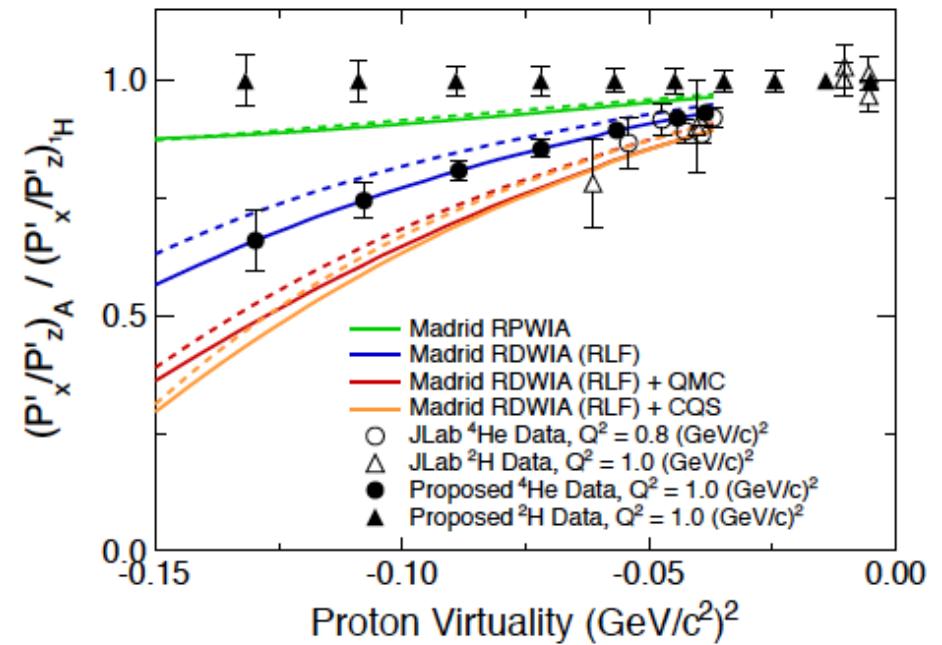
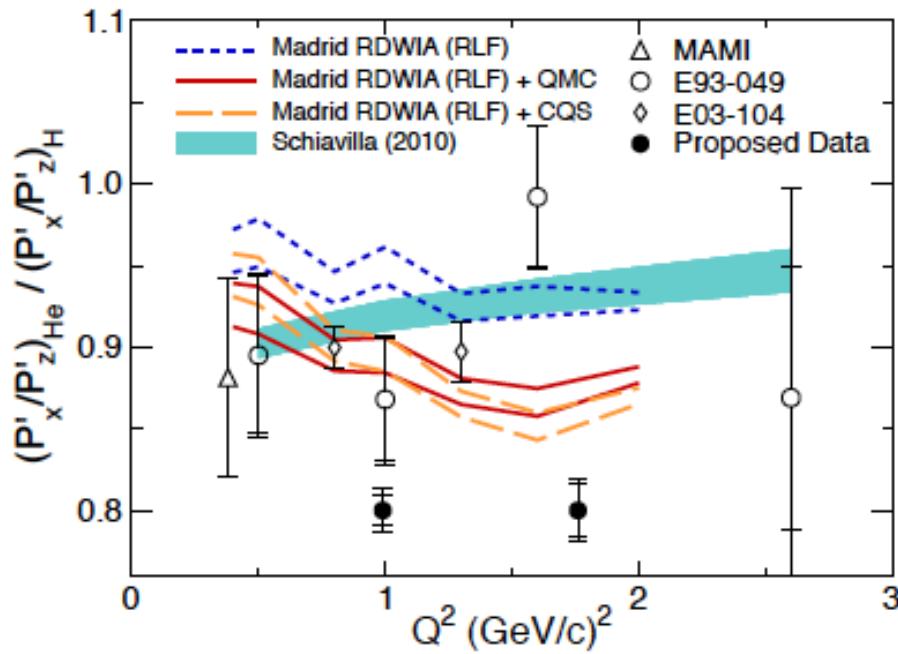
E12-11-112: Precision measurement of the isospin dependence in 2N & 3N SRC regions.



- Measure wide range of kinematics
- Measure with many targets: e.g. D2, H3, He3, He4, Be, C, Cu, Au
- Shown above is the kinematic reach of the Hall C E12-06-105 measurements

# Search for Medium Modified Form Factors

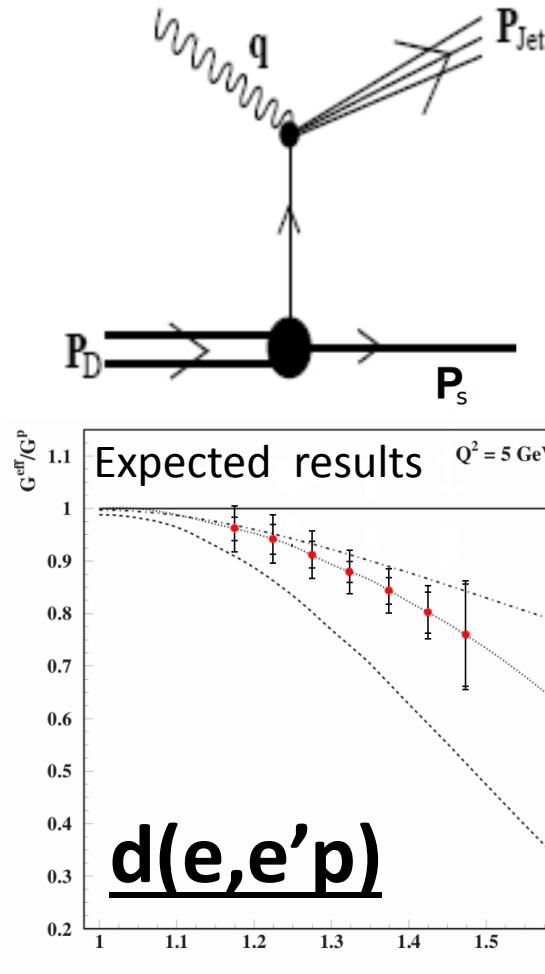
E12-11-002: Recoil Polarization Measurements of  ${}^4\text{He}(\text{e},\text{e}'\text{p}){}^3\text{H}$ ,  $\text{D}(\text{e},\text{e}'\text{p})\text{n}$ , and  $\text{H}(\text{e},\text{e}'\text{p})$



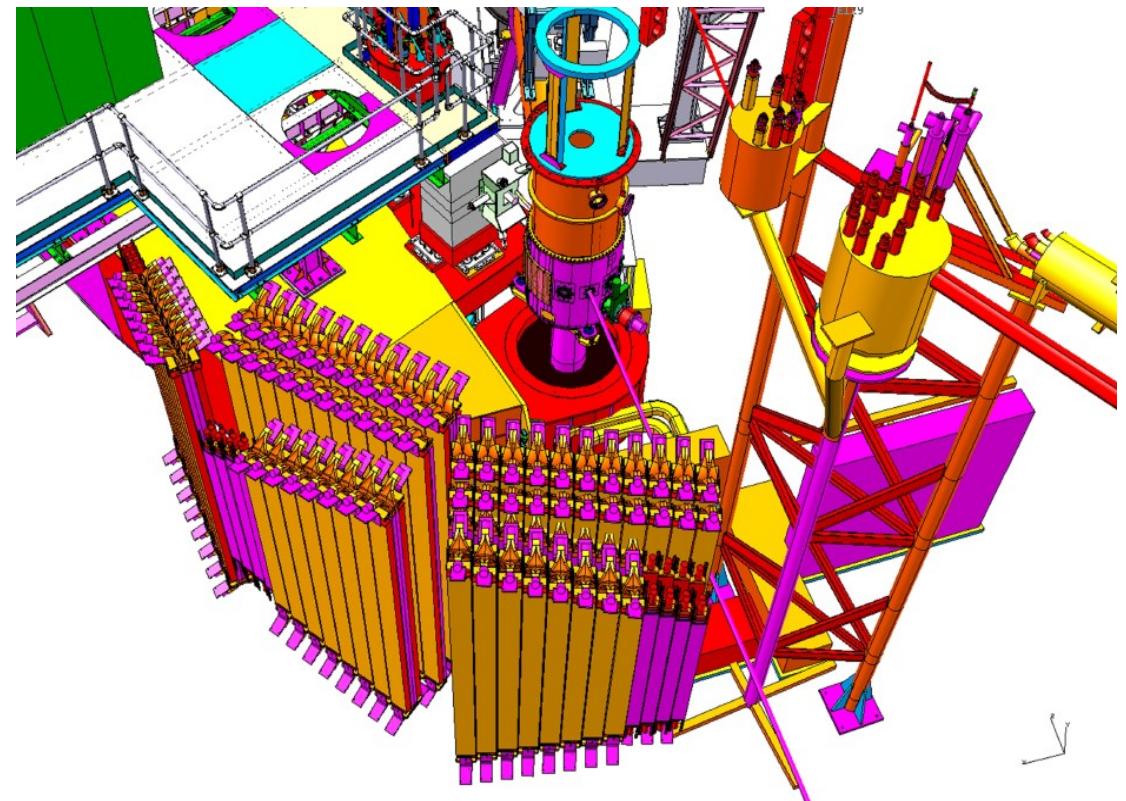
- Upcoming measurements will push the precision and reach of these measurements and now include deuterium.

# In-Medium Structure Functions

E12-11-107: In Medium Nucleon Structure Functions, SRC, and the EMC effect



Large Acceptance Detector for Jefferson Lab Hall C



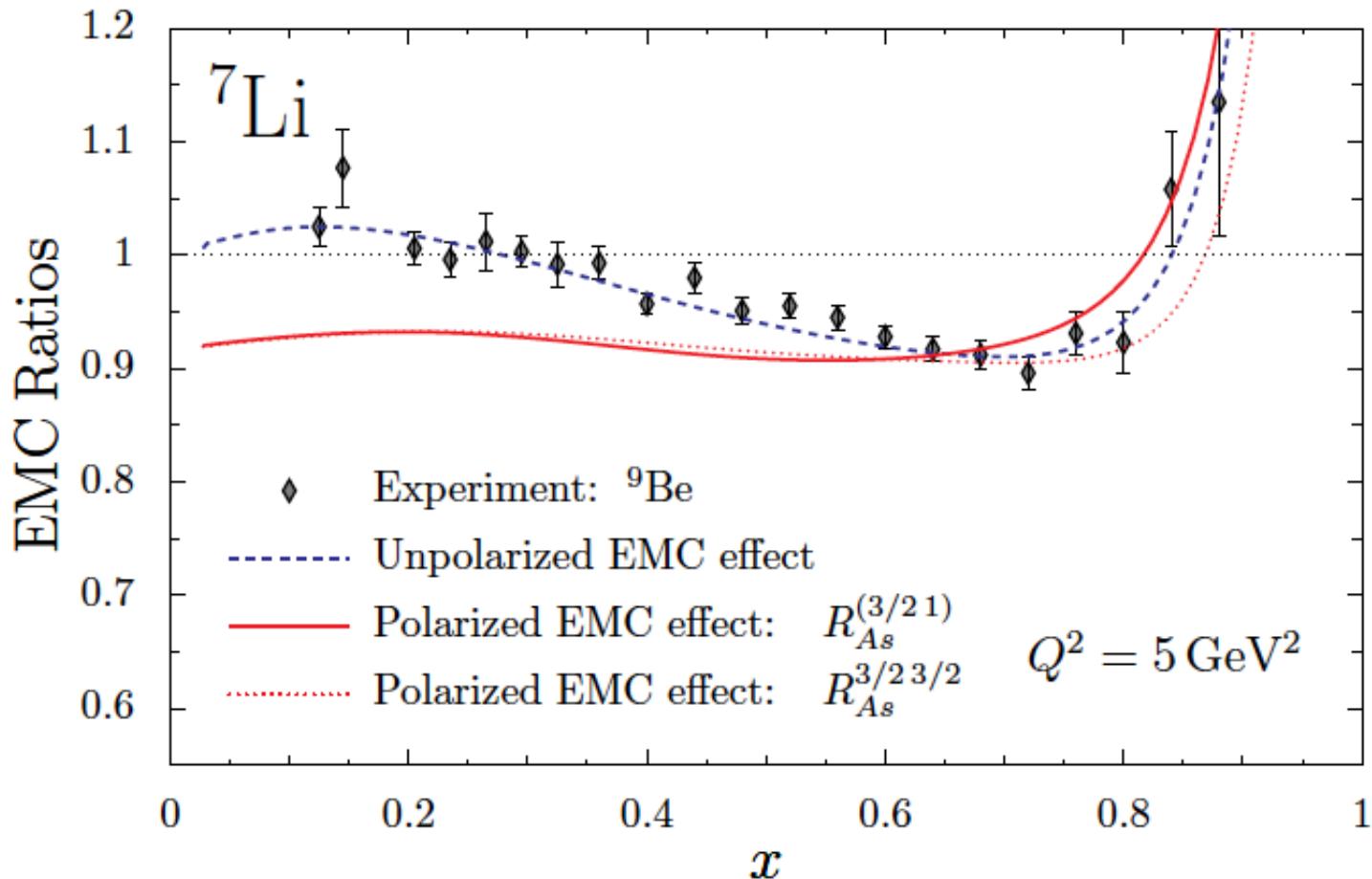
Spectator Tagging with Bonus, E12-06-113: The Structure of the Free Neutron at Large  $x$ .

In the future these measurements can be done with an EIC over to low  $x$ .

(see talks by C. Weiss and C. Hyde)

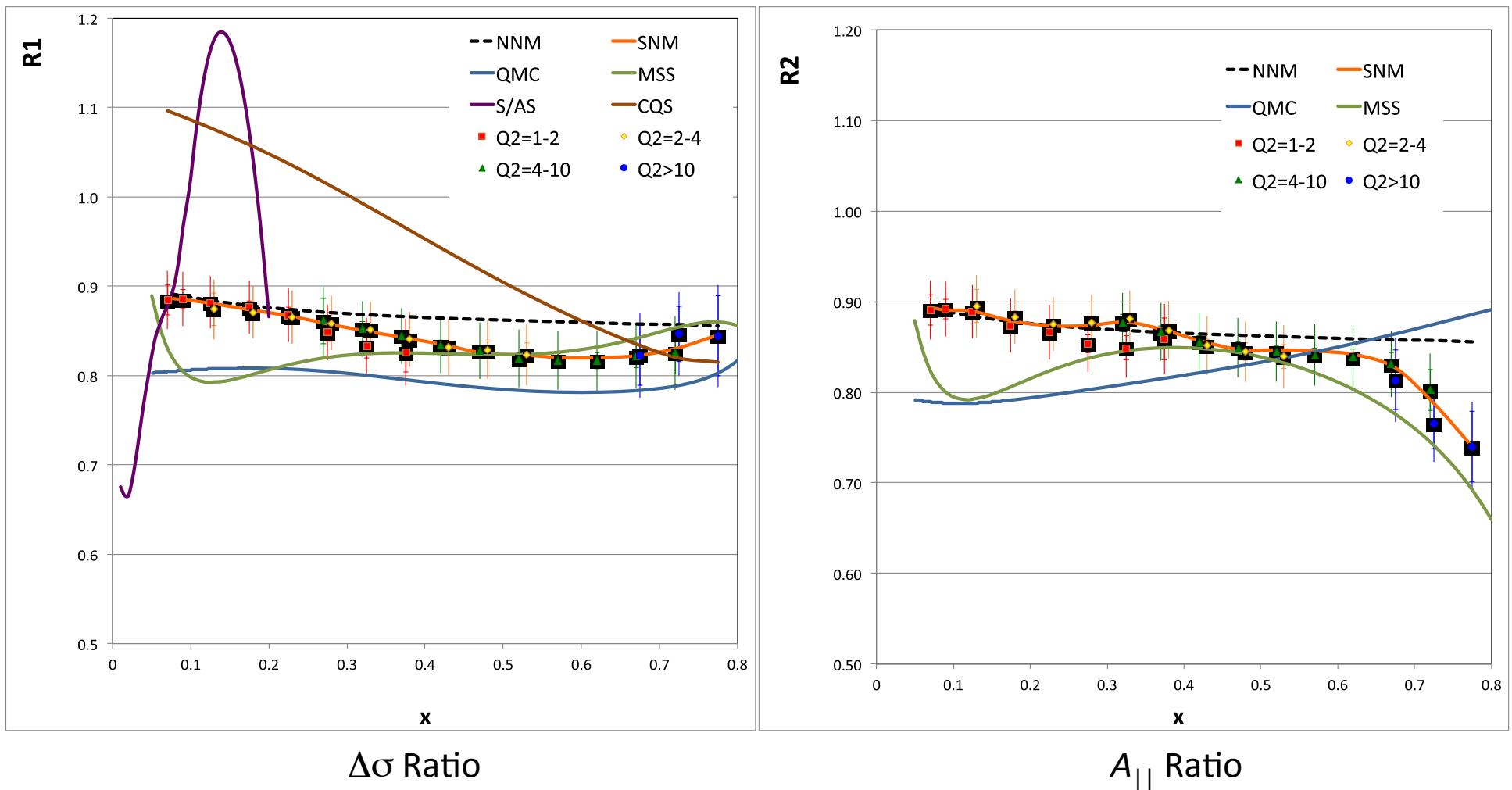
# Polarized EMC Effect

I. C. Cloet, W. Bentz and A. W. Thomas, Phys.Lett.B **642** (2006) 210-217.



# Polarized EMC = Every Model Cannot

E12-14-001: The EMC Effect in Spin Structure Functions



# Summary

- Many new results showing the effect of high initial-state momentums (both theory and experiment).
- Dominated by short-range proton-neutron tensor correlations .
- New DIS data points to EMC effect being a local density effect.
- These two effects seem to be strongly correlated.
- Open Questions
  - What exactly is the high momentum tail (hadronic and/or partonic)?
  - Can we use of the EMC-SRC connection to make new insights?
  - Can we finally solve the 31 year old EMC effect puzzle?!
- Many New EMC ( $x < 1$ ) and SRC ( $x > 1$ ) Experiments Coming with 12GeV Jefferson Lab, including  ${}^3\text{H}$  &  ${}^3\text{He}$ .
- Measurements such as  ${}^{40}\text{Ar}(e,e'p)$  import for other subfields of nuclear physics.
- Revisiting topics such as importance of correlations in dense nuclear mater via efforts such as the CLAS data mining project.

# Changing Picture Of Nuclear Matter

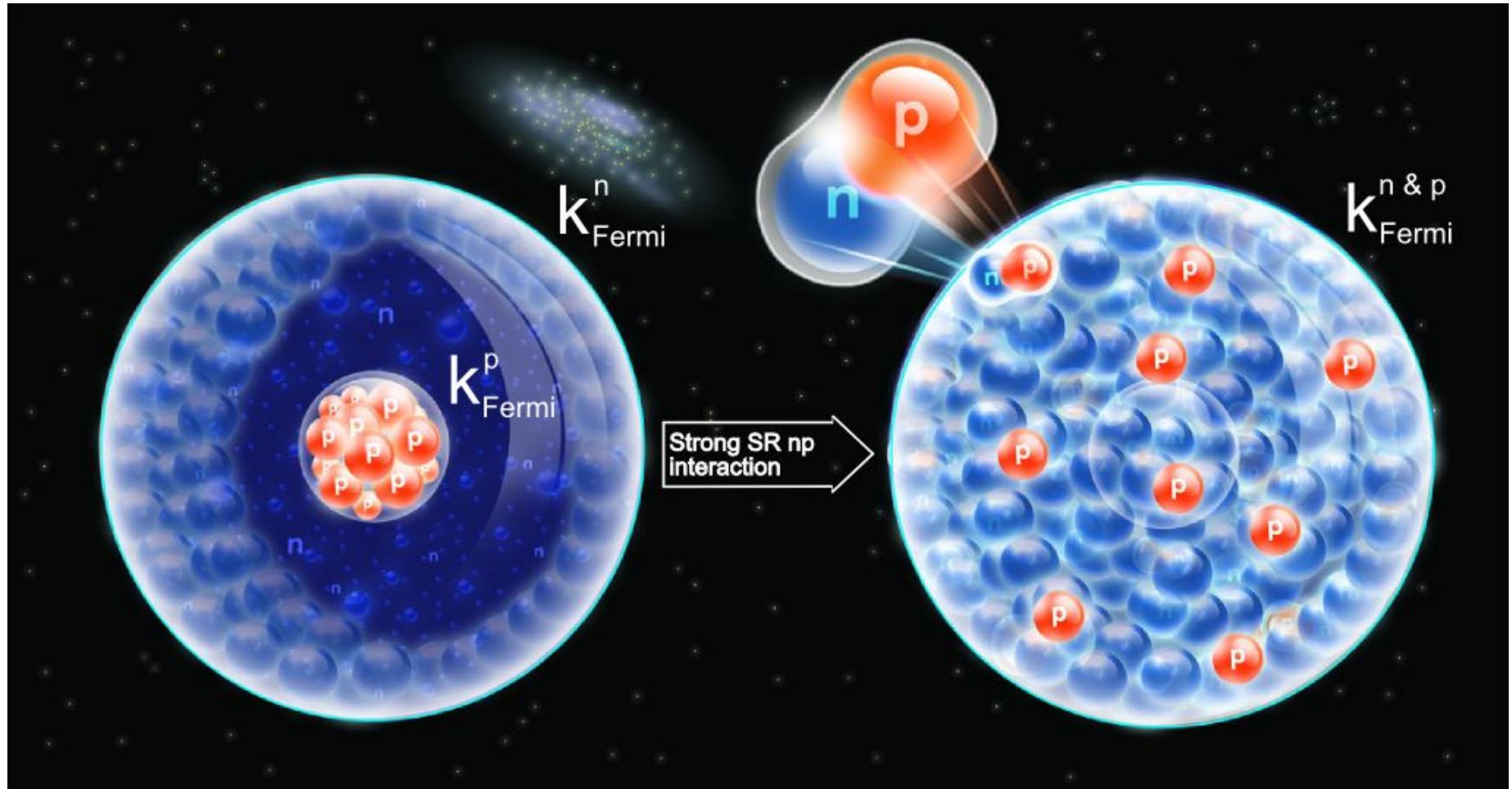


Image from CERN Courier 49N1 (2009) 22-24.

# List Of Discussed Upcoming Experiments

## Jefferson Lab Hall A

- \* E12-11-112  ${}^3\text{He}/{}^3\text{H}$   $x>1$
- \* E12-14-011  ${}^3\text{He}/{}^3\text{H}$  ( $e,e'p$ )
- \* E12-14-012  ${}^{40}\text{Ar}(e,e'p)$  in collaboration with neutrino community

## Jefferson Lab Hall B

- \* E12-06-113 Spectator Tagging
- \* E12-14-001 Polarized EMC

## Jefferson Lab Hall C

- \* E12-06-105  $x>1$
- \* E12-11-002 polarization transfer
- \* E12-11-107 ( $e,e'p$ ) EMC-SRC